 Manufacture of free-form eyeglass lenses using laser technology.

Within the ophthalmic optics, the progressive lenses are the most complex. Currently the calculated free-form surfaces are manufactured using the metal cutting process. Converting to a laser processing method is desired. This article describes the advantages which laser-supported manufacture of progressive lenses could offer as well as the benefits for the end-user.

Not only have the requirements of the ophthalmic lenses drastically changed in the past 50 years, but also the expectations of the consumers. Was it a mere single vision lens support in the last century, it is today not only a fashion accessory, but it also enables individually optimized sight for different distances in one single lens - the progressive lens!

The progressive lens and its’ aberrations

The simplest form of an ophthalmic lens is the single vision lens. It combines a strength in a sphere-cylindrical combination (i.e sph. -2.00 cyl + 1.00). Single vision lenses are used either as far-sight glasses (short-sightedness, far-sightedness, astigmatism) or as reading glasses for near distances. Both variations only have one goal in mind; the correction of defective vision in the distance or proximity.

Progressive lenses or variable strength lenses distinguish themselves in that they combine different strengths within, with the advantage of using only a single lens for all sight needs (far-sight, near-sight and in-between sights). The characteristic feature of the progressive lens is therefore the changes in effects from the upper to the lower are of the glass. These changes are achieved through the radius’ of curvature, meaning, the changes in strength are due to the curvature of the glass itself.

Despite the many advantages, these lenses do have their limitations due to their surficial geometry with respect to changes in strengths in the form of aberrations. These aberrations are known to the wearer as swim or swing effects, whereas vision seems to be blurred. Due to this the peripheral perception is limited (perception of space and orientation).

According to different designs and product philosophies, these aberrations can be optimized or emphasized where need be. As such, the same portion of aberrations can be dispersed over a larger surface area, with the result of a different design as when spreading over a smaller surface area. Typical for the different designs are the areas in which the physiological perception of the aberration is beneath the aligning power if the eye. Above the principalities of aberrations, the number of calculated points, which are used for optimization and manufacture, play a role. Also, the individual parameters, like frame data and customer parameters, in short, all parameters which have an

Fig.1: Structure of a progressive lens
influence on the effect on the glass, flow into this calculation. As individual as the physiology of sight is for each human being, as individually can lenses be designed, in order to meet the requirements of today's age. The true art of producing such complex and manifold lenses successfully, lies on one side in the hands of the glass designer who tries to control the aberrations as best as he can. On the other side on the possibilities of manufacturing technology, manufacturing lenses with errors of accuracy coming as close as possible to the calculations of the lens designer.

**Manufacture using Lasers**

The classic lens manufacture starts with a semi-finished product. Thereby the convex side needs not be further worked on. The surface data (radius' of curvature) flow into the optimized calculation of the entire lens. The manufacture of the progressive lens design and its' optimization, with respect to aberrations and all other data relevant to the wearer, is then applied on the "inner side" by milling/turning and subsequent soft tool polishing.

Lasers are already applied for the permanent labelling of necessary markings. It is therefore evident to expand this application with regard to process optimization and quality increase.

The manufacturing process using laser technology underlies the duty of improving errors using state-of-the-art technology.

As mentioned earlier, the art lies therein, implementing the lens designers' data within the production process, with the aim of excluding any geometrical changes during production.

The following suggestions can be made for process optimization and quality increase:

Regarding the pure mathematical possibility of lens calculation, optimization and design configuration, the wish for surface roughness reduction becomes clear, so that further polishing processes, with an associated surface alteration (geometric change) can be excluded. This can possibly be achieved by the application of a laser which replaces the mechanical shape through milling/turning or polishing. For the implementation one would first have to clarify, which lasers are suitable for which eye glass material.

Lenses underlie certain requirements – which are summarised under ISO 8980. This norm, which has been elaborated under the participation of German experts, names the fundamental requirements of rough-edged finished lenses, like the tolerance of dioptric and prismatic effects, the glass diameter and the glass thickness, as well as the surface quality. Furthermore, the methods of testing and measuring are specified within this norm. Are merely the lens surfaces and surface errors judged due to the manufacturing process, one consistently finds error pictures time and again, even though not defined in detail with ISO 8980, they do have a direct effect on the visual perception of the wearer. This is due to spiral formed planar defects or punctual errors in the glass centre, whose causes are found in the milling/turning processes or concentric circles which indicate polishing residue. Here it is necessary to exclude such mistakes using precision increase improvements.

A further essential point is the reduction of measurement errors after ISO 8980, which currently lies at least 0,12 dpt. End-users can perceive and differentiate with a subjective refraction (lens determination) of 0,12 dpt. Commonly, the refraction or lens order, takes place in 0,25 dpt steps. The goal is not only to offer the optician an order program in ≤ 0,12 dpt steps, but also to bring the total aberrations (lens determination + measurement aberration) to a value of ≤ 0,12 dpt. Currently this value, in the worst case, lies by at least 0,25 dpt (fig.2), whereas with progressive lens intolerance a reduction to 0,12 dpt has shown to improve sight subjectively.

![Fig.2: Total deviation](image-url)
Are the measured tolerances significantly reduced, the reverse applies, namely, that the image characteristics based on astigmatisms, spherical aberrations, etc in the transition areas and border zones are improved. This means that the progression-zones (transition from far-sight area to reading area = the key area) are perceived as larger / wider by the wearer. (fig.3).

![Fig.3: Comparision intermediate area](image.png)

The “swim” or “Swing” effects are also reduced. The use of lasers in production shall therefore enable the precise manufacture of lenses which lie close to the individually determined values of the end-user (aberration of $< 0.12$ dpt). With the help of a laser, higher production accuracy shall be achieved than through conventional manufacture using milling/turning and polishing. For that purpose, it is necessary to reduce the measurement errors, in order to translate the customer data into a more precise manufacturing process.

**Conclusion**

Due to their precision, lasers have established themselves in many areas; laser-cutting, laser-welding, or also in refractive corneal surgery the laser has become an essential component. The progressive lens is the most complex product in the area of ophthalmic optics. Their acceptances, or rather their possibilities of adjustment with regard to aberrations, lie in direct relation to the manufacturing process. The use of lasers could take a leading role in realising the herein discussed improvements for the manufacture of progressive lenses.

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